

Having thus defined the invention, the following is claimed:

1. A method of forming an elongated tubular metal blank with first and second ends, at least one of said ends being open, into a tubular structural component having a predetermined outer configuration, said method comprising:

5 (a) providing a shape imparting shell formed from a low permeability, rigid material, said shell being in the form of first and a second half shell, each of which includes an inner surface defining said predetermined shape, an outer support and mounting surface and spaced lateral edges which edges define a parting plane between said two half shells when said half shells are brought together to form said shell;

10 (b) providing a first die member with an upper side and a lower side and having a non-magnetic support framework for carrying said first half shell mounted in said framework by a cast compression force transmitting non-magnetic material with said laterally spaced edges of said first half shell facing outwardly from said lower side of said first die member;

15 (c) providing a second die member with an upper side and a lower side and having a non-magnetic support framework for carrying said second half shell mounted in said framework by a cast compression force transmitting non-magnetic material with said laterally spaced edges of said second half shell facing outwardly from said upper side of said second die member;

(d) plugging said open end or ends of said tubular blank;

(e) placing said plugged blank into said second half shell in said second die member;

20 (f) moving said first die member relative to said second die member to capture said blank in said shape imparting shell;

(g) forming said tubular blank into said component by inductively heating axial portions of said blank by axially spaced conductors adjacent said shell while or before forcing gas at a high pressure into said plugged blank until said blank conforms to at least a portion of the inner surfaces of said first and second half shells to form said component.

2. The method as defined in claim 1 wherein said rigid material is ceramic having a high hardness.

3. The method as defined in claim 1 wherein said rigid material is fused silica impregnated with nitrogen.

4. The method as defined in claim 1 wherein said rigid material is selected from the class consisting of silicon nitride, silicon carbide, beryllium oxide, boron oxide, and xirconia.

5. The method as defined in claim 4 wherein said cast material is castable ceramic having a strength and hardness substantially less than said rigid material.

6. The method as defined in claim 2 wherein said cast material is castable ceramic having a strength and hardness substantially less than said rigid material.

7. The method as defined in claim 1 wherein said cast material is castable ceramic having a strength and hardness substantially less than said rigid material.

8. The method as defined in claim 7 wherein said framework is machined metal.

9. The method as defined in claim 8 wherein said machined metal is aluminum.

10. The method as defined in claim 8 wherein said framework is machined metal.

11. The method as defined in claim 10 wherein said machined metal is aluminum.

12. The method as defined in claim 1 wherein said tubular blank has only two open ends.

13. The method as defined in claim 1 wherein said predetermined shape has an axial profile and including:

(h) preforming said tubular blank into an axial profile generally confirming to said axial profile of said predetermined shape.

14. The method as defined in claim 13 including:
- (i) heating said tubular blank before forming said blank.

15. The method as defined in claim 14 wherein said heating is by passing a heating current through said tubular blank.

16. The method as defined in claim 1 including:
- (h) heating said tubular blank before forming said blank.

17. The method as defined in claim 16 wherein said heating is by passing a heating current through said tubular blank.

18. The method as defined in claim 1 wherein said induction heating is varied along the length of said tubular blank to modulate the temperature/time pattern along said length.

19. The method as defined in claim 18 wherein said variation is by varying the frequency of the alternating current powering said axially spaced conductors.

20. The method as defined in claim 18 wherein said variation is by varying the heating time of the alternating current powering said axially spaced conductors.

21. The method as defined in claim 18 wherein said variation is by varying the distance said axially spaced conductors are from said shell.

22. The method as defined in claim 18 wherein said variation is by varying the spacing between said axially spaced conductors.

23. The method as defined in claim 18 wherein said variation is by varying the power of the alternating current powering said axially spaced conductors.

24. The method as defined in claim 18 wherein said predetermined shape has an axial profile and including:

(h) preforming said tubular blank into an axial profile generally confirming to said axial profile of said predetermined shape.

25. The method as defined in claim 24 including:

(i) heating said tubular blank before forming said blank.

26. The method as defined in claim 18 wherein said heating is by passing a heating current through said tubular blank.

27. The method as defined in claim 18 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

28. The method as defined in claim 27 including varying said quenching along said axial length.

29. The method as defined in claim 28 wherein said quench variation is by varying the flow rate of quenching fluid along said length.

30. The method as defined in claim 28 wherein said quench variation is by changing location of said quenching operation along said length.

31. The method as defined in claim 1 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

32. The method as defined in claim 31 including varying said quenching along said axial length.

33. The method as defined in claim 32 wherein said quench variation is by varying the flow rate of quenching fluid along said length.

34. The method as defined in claim 32 wherein said quench variation is by changing location of said quenching operation along said length.

35. The method as defined in claim 31 wherein said predetermined shape has an axial profile and including:

(h) preforming said tubular blank into an axial profile generally confirming to said axial profile of said predetermined shape.

36. The method as defined in claim 35 wherein said heating is by passing a heating current through said tubular blank.

37. The method as defined in claim 36 including:

(h) heating said tubular blank before forming said blank.

38. The method as defined in claim 1 including feeding of metal from said blank into said shell while said blank is being formed.

39. The method as defined in claim 38 wherein said induction heating is varied along the length of said tubular blank to modulate the temperature/time pattern along said length.

40. The method as defined in claim 39 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

41. The method as defined in claim 40 including varying said quenching along said axial length.

42. The method as defined in claim 1 including sensing the pressure of said gas in said shell and controlling the gas pressure of the gas forced into said tubular blank to a preselected value.

43. The method as defined in claim 42 wherein said preselected value is in the range of about 200-1000 psi.

44. The method as defined in claim 1 wherein said high pressure is in the range of 200-1000 psi.

45. The method as defined in claim 44 wherein said induction heating is varied along the length of said tubular blank to modulate the temperature/time pattern along said length.

46. The method as defined in claim 45 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

47. The method as defined in claim 46 including varying said quenching along said axial length.

48. The method as defined in claim 44 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

49. The method as defined in claim 48 including varying said quenching along said axial length.

50. The method defined in claim 1 wherein said metal blank is a steel blank capable of metallurgical and physical changes by heating and quenching.

51. The method as defined in claim 50 wherein said metal blank has a thickness in the range of 0.40-.350 inches.

52. The method as defined in claim 1 wherein said metal blank is an aluminum blank capable of metallurgical and/or physical changes by heating and quenching.

53. A die set for forming an elongated tubular metal blank with first and second plugged ends into a tubular structural component, said die set comprises a shape imparting shell formed from a low permeability, rigid material, said shell being in the form of first and a second half shell each of which includes an inner surface defining said predetermined shape, an outer support and mounting surface and spaced lateral edges which edges define a parting plane between said two half shells when said half shells are brought together to form said shell; providing a first die member with an upper side and a lower side and having a non-magnetic support framework for carrying said first half shell mounted in said framework by a cast compression force transmitting non-magnetic material with said laterally spaced edges of said first half shell facing outwardly from said lower side of said first die member; and, providing a second die member with an upper side and a lower side and having a non-magnetic support framework for carrying said second half shell mounted in said framework by a cast compression force transmitting non-magnetic material with said laterally spaced edges of said second half shell facing outwardly from said upper side of said second die member whereby said first die member is movable relative to said second die member to capture said blank in said shape imparting shell.

54. The die set as defined in claim 53 wherein said rigid material is fused silica.

55. The die set as defined in claim 53 wherein said rigid material is selected from the class consisting of silicon nitride, silicon carbide, beryllium oxide, boron oxide, and xirconia.

56. The die set as defined in claim 53 wherein said cast material is castable ceramic having a strength and hardness substantially less than said rigid material.

57. The die set as defined in claim 56 wherein said framework is machined metal.

58. The die set as defined in claim 57 wherein said machined metal is aluminum.

59. A method of forming an elongated tubular metal blank with a length between first and second ends, at least one of said ends being open, into a tubular component having a predetermined outer configuration, said method comprising:

(a) plugging said open end or ends of said tubular blank;

5 (b) placing said plugged blank into a cavity with an inner surface surrounding said blank and having said predetermined outer configuration;

(c) forming said tubular blank into said component by inductively heating axial portions along the length of said blank by axially spaced conductors adjacent said cavity while forcing gas at a high pressure into said plugged blank until said blank conforms to at least a portion of said inner surface of said cavity to form said component.

60. The method as defined in claim 59 wherein said tubular blank has only two open ends.

61. The method as defined in claim 59 wherein said predetermined shape has an axial profile and including:

(d) preforming said tubular blank into an axial profile generally conforming to said axial profile of said predetermined shape.

62. The method as defined in claim 61 including:

(e) heating said tubular blank before forming said blank.

63. The method as defined in claim 62 wherein said heating is by passing a heating current through said blank.

64. The method as defined in claim 63 wherein said heating current is an A.C. current.



65. The method as defined in claim 59 wherein said induction heating is varied along the length of said tubular blank to modulate the temperature/time pattern along said length.

66. The method as defined in claim 65 wherein said variation is by varying the frequency of the alternating current powering said axially spaced conductors.

67. The method as defined in claim 65 wherein said variation is by varying the distance said axially spaced conductors are from said shell.

68. The method as defined in claim 65 wherein said variation is by varying the spacing between said axially spaced conductors.

69. The method as defined in claim 65 wherein said variation is by varying the power of the alternating current powering said axially spaced conductors .

70. The method as defined in claim 59 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

71. The method as defined in claim 70 including varying said quenching along said axial length.

72. The method as defined in claim 71 wherein said quench variation is by varying the flow rate of quenching fluid along said length.

73. The method as defined in claim 71 wherein said quench variation is by changing location of said quenching operation along said length.

74. The method as defined in claim 65 including transferring said formed component into a quench station and quenching said component along the axial length of said component.

75. The method as defined in claim 59 including sensing the pressure of said gas in said shell and controlling the gas pressure of the gas forced into said tubular blank to a preselected value.

76. The method as defined in claim 75 wherein said preselected value is in the range of about 200-1000 psi.

77. The method as defined in claim 59 wherein said high pressure is in the range of 200-1000 psi.

78. The method as defined in claim 59 including forming said cavity from a low permeability, rigid material and supporting said cavity in a cast non-magnetic material.

79. The method as defined in claim 78 wherein said rigid material is ceramic having a high hardness.

80. The method as defined in claim 78 wherein said rigid material is fused silica.

81. The method as defined in claim 80 wherein said rigid material is selected from the class consisting of silicon nitride, silicon carbide, beryllium oxide, boron oxide, and xirconia.

82. The method as defined in claim 59 wherein said high pressure is in the range of 200-1000 psi.

83. A method of forming an elongated tubular metal blank with a length between first and second ends, at least one of said ends being open, into a tubular component having a predetermined outer configuration, said method comprising:

- (a) plugging said open end or ends of said tubular blank;
- (b) placing said plugged blank into a cavity with an inner surface surrounding said blank and having said predetermined outer shape;

(c) forming said tubular blank into said component by inductively heating said blank along its length while forcing gas at a high pressure into said plugged blank until said blank conforms to at least a portion of said inner surface of said cavity to form said component; and,

10 (d) transferring said formed component into a quench station and quenching said component along said axial length.

84. The method as defined in claim 83 including varying said quenching along said axial length.

85. The method as defined in claim 84 wherein said quench variation is by varying the flow rate of quenching fluid along said length.

86. The method as defined in claim 84 wherein said quench variation is by changing location of said quenching operation along said length.

87. The method as defined in claim 83 wherein said induction heating is varied along the length of said tubular blank to modulate the temperature/time pattern along said length.

88. The method as defined in claim 87 wherein said variation is by varying the frequency of the alternating current powering said axially spaced conductors.

89. The method as defined in claim 87 wherein said variation is by varying the heating time of the alternating current powering said axially spaced conductors.

90. The method as defined in claim 87 wherein said variation is by varying the spacing between said axially spaced conductors.

91. The method as defined in claim 87 wherein said variation is by varying the power of the alternating current powering said axially spaced conductors.

92. The method as defined in claim 83 including sensing the pressure of said gas in said shell and controlling the gas pressure of the gas forced into said tubular blank to a preselected value.

93. The method as defined in claim 92 wherein said preselected value is in the range of about 200-1000 psi.

94. The method as defined in claim 83 wherein said high pressure is in the range of 200-1000 psi.

95. The method as defined in claim 83 including forming said cavity from a low permeability, rigid material and supporting said cavity in a cast non-magnetic material.

96. The method as defined in claim 95 wherein said rigid material is fused silica.

97. The method as defined in claim 96 wherein said rigid material is selected from the class consisting of silicon nitride, silicon carbide, beryllium oxide, boron oxide, and xirconia.

98. The method as defined in claim 83 wherein said quenching cools said component to a given temperature above ambient for a time to provide arrested cooling.

99. A method of forming an elongated tubular metal blank with a length between first and second ends, at least one of such ends being open, into a tubular component having a predetermined shape, said method comprising:

- (a) plugging said open end or ends of said tubular blank;
- 5 (b) placing said plugged blank into a cavity with an inner surface surrounding said blank and having said predetermined outer shape;
- (c) forcing gas at a high pressure into said plugged blank until said blank conforms to at least a portion of said inner surface of said cavity to form said component;
- (d) inductively heating said blank along its length while said blank is in said cavity

- 10      whereby said blank is heated before and/or while it is formed; and,  
            (e)      varying the induction heating along said length.

100.    A method as defined in claim 99 wherein said induction heating is by inductors spaced along the length of said blank.

101.    The method as defined in claim 100 wherein said variation is by varying the frequency of the alternating current powering said axially spaced conductors.

102.    The method as defined in claim 100 wherein said variation is by varying the heating time of the alternating current powering said axially spaced conductors.

103.    The method as defined in claim 100 wherein said variation is by varying the spacing between said axially spaced conductors.

104.    The method as defined in claim 100 wherein said variation is by varying the power of the alternating current powering said axially spaced conductors.

105.    A method as defined in claim 100 wherein said variation is by varying the permeability of the flux field of selected spaced conductors.

106.    A method as defined in claim 105 wherein said flux field is varied by a flux concentrator positioned along the length of said blank.

107.    A method as defined in claim 105 wherein said flux field is varied by a Faraday shield positioned along said length of said blank.